6.—NOTES ON LATERITE IN THE DARLING RANGE NEAR PERTH, WESTERN AUSTRALIA.

By

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Laterite is widespread in Western Australia and it has been reported on by geologists and pedologists who have examined large tracts of country in connection with mining and agricultural activities. Mineral chemists and mineralogists have also added to our knowledge of the subject.

It is not intended to review this literature here, but to place on record certain results of work done by the present author in the study of laterite as a spare-time pursuit and to draw attention to certain inferences which result therefrom. The work done on an exposure of laterite at Parkerville and reported in this paper, formed the basis of a contribution to a symposium on "Laterite in Australia" at the Perth Meeting of the Australian and New Zealand Association for the Advancement of Science held in August, 1947.

The literature concerning laterite abounds in hypotheses of origin and these may be divided into two main groups. One group of hypotheses involves solution, transport to a new site and re-deposition thereat of the laterite constituents. The other group constitutes variations of the one theme whereby laterite is deemed to have been left behind when the non-lateritic constituents, that is, the whole of the combined silica, the lime, magnesia and alkalies, have been removed in solution.

Those hypotheses which involve the movement of lateritic constituents in solution may be further grouped according to the direction of the movement of the laterite-forming solutions and the nature of the influences governing that movement.

The "capillarity school" of thought envisaged the movement of these solutions upwards from the water-table under the influence of capillary forces. Having reached the surface, or come near thereto, evaporation and/or oxidation leads to the deposition of the oxides of iron and aluminium, or, alternatively, the uppermost layers of the soil are replaced by these oxides. Simpson (1912), Woolnough (1918) and others considered capillarity to be the chief influence controlling the movement of laterite-forming solutions.

Another hypothesis, advanced by Prescott (1931), involves the downward movement of iron- and aluminium-bearing soil-waters under the influence of gravity: upon reaching a lower horizon, changed conditions of soil acidity cause the precipitation of laterite constituents as an illuvial horizon.

A third school of thought accepts the views advanced by Campbell (1910, 1917). Those who accept this hypothesis consider that iron or both iron and aluminium are taken into solution in percolating meteoric waters which,

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under gravitational influences, move downwards to the water-table and then laterally in the zone of saturation : seasonal oscillation of the water-table causes alternate wetting and drying-out of a lower zone of the soil profile, leading to the deposition therein of iron and/or aluminium oxides.

It might be expected that a detailed examination of laterite exposures where railway or road cuttings and the like pass right through the laterite into the underlying materials might yield evidence of a critical nature which may lead to the selection of one or another of the hypotheses as applying to the Darling Range laterite. If, for example, the hypothesis involving solution, transportation laterally and re-deposition holds, it would not be expected that a sharp and distinct boundary would exist between laterite over a basic dyke and that overlying the granite traversed by such dykes, this being essentially the geological nature of the Darling Range. Further, if the distinctive structure of the basic dyke rock should appear in the laterite, either there must have been a selective replacement of the parent rock by the laterite constituents, or the laterite must be a skeletal body left upon the removal of those constituents of the parent rock which are not present in the laterite. Again, should the laterite retain the structure of the parent rock and should its alumina/ferric oxide ratio be approximately the same, it is considered that no hypothesis involving solution, transport to a new site and re-deposition can be accepted as indicating the origin of that particular occurrence. Alternatively, if the first products of weathering form a plastic clay, swelling and shrinking during alternate water-saturation and desiccation would be expected to destroy very quickly any vestige of the structure of the parent rock : this would not be expected to occur, however, should a non-plastic kaolin body be formed in the first place.

These are but a few of the possibilities, each of which is dependent upon the manner of evolution of the laterite. The literature concerning laterite is a prolific source of such possibilities, and a consideration of these enables one to select suitable exposures for detailed study, exposures which might be expected to yield information of a critical value.

The basic dyke rocks have a readily recognisable, distinctive structure, should it be preserved in laterite derived therefrom, whereas the granite and granitic gneisses generally have not. Consequently, in the road and rail cuttings and gravel pits of the Darling Range, a search was made for massive laterite which could be seen to overlie recognisable basic-dyke rock or in which remnants of the basic dyke could be recognised.

North of the present railway station at Mount Helena there is an old railway cutting where there is exposed an excellent example of the weathering of a basic dyke cutting through the granite, with what appears to be laterite developed over both. On the surface of the ground near-by it was not possible to detect any difference between the weathering product from the granite and that from the basic dyke rock. In the sides of the cutting, however, the position and attitude of the parent basic dyke are clearly evident and the boundary between what is probably laterite derived from the basic dyke and that formed on the granite is sharp and distinct. The product of weathering derived from the basic rock is markedly different from that over the granitic rocks : it is very dark brown as compared with the light yellowish brown of the laterite over the granite ; it is denser and more even in structure and preserves the system of cracks formed during the initial fracturing and spheroidal weathering of the rock. The laterite overlying the granitic rocks

is thin and is underlain by soft, friable, gritty clay and concretionary structures are well developed in it. No further work has been done on this exposure because the profile is not sufficiently exposed to give information on the nature of the materials beneath the laterite formed over the basic dyke.

At Parkerville, however, there is an exposure that does not suffer from this deficiency. In the vicinity of the Public Hall near the railway station and crossing, a number of pits have been dug to obtain laterite and clay for road and other civic amenities, and to provide level ground alongside the hall. In doing this, a face was cut which reveals the top twelve feet or so of the profile of a weathered basic dyke rock, a typical quartz-dolerite with the characteristic ophitic texture of this rock-type (*see* Plate II, fig. 1). An analysis of the rock is given in Table 1.

TABLE 1

	Dolerite.	Laterite.
	%	%
SiO_2 (total)	50.63	15.83
(free)	....	(5.66)
(combined)	....	(10.17)
Al_2O_3	13.20	31.68
Fe_2O_3	1.70	24.95
FeO	10.06	2.52
MnO	0.17	n.d.
MgO	7.63	0.62
CaO	12.27	0.01
Na_2O	2.00	0.14
K_2O	0.16	*nil*
H_2O-	0.03	2.69
H_2O+	0.59	19.55*
TiO_2	0.91	2.07
P_2O_5	0.15	0.09
	99.50	100.15
Molecular Ratios :		
Combined silica/alumina	....	0.54
Alumina/ferric oxide†	2·05	1.99

* By ignition loss.
† The ferrous oxide of the quartz-dolerite in excess of that of the laterite is regarded as converted into ferric oxide by the weathering processes.

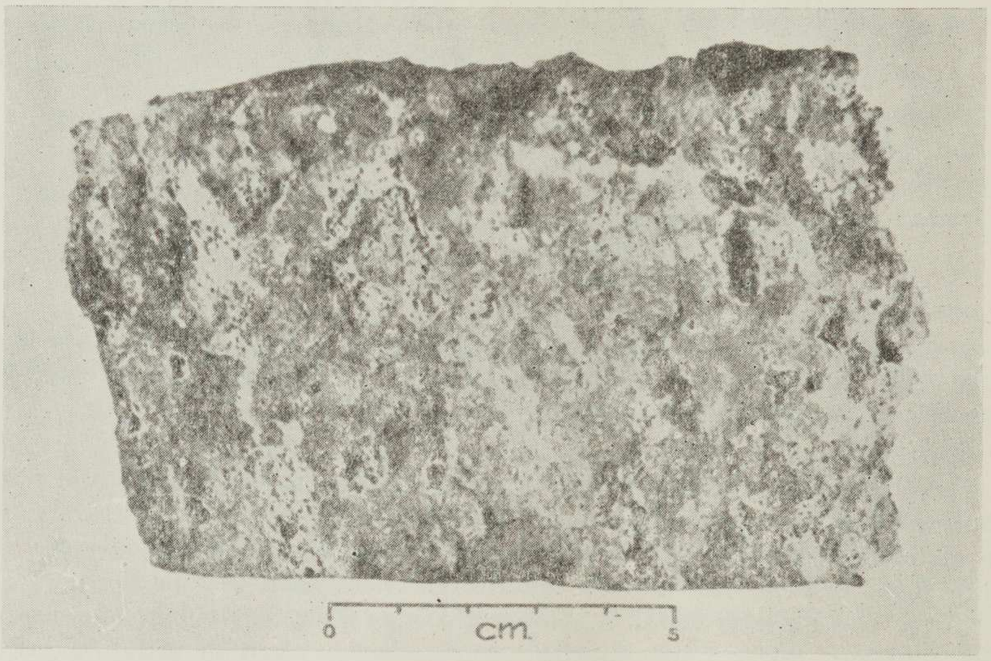
Analysts : S. E. Terrill and D. Burns.

The top eighteen inches to thirty inches of the profile is loose and rubbly with much root and organic matter. The stones of the rubble are rarely more than an inch and a half across and, when broken across, are evenly coloured a very dark brown—no banded concretions were seen in this spot. Below the rubbly top horizon there is a layer three to four feet thick, of porous to dense, mottled, fairly hard laterite, rather darker than is usual in laterite overlying granite, but otherwise similar to some of the forms in which that laterite occurs. The laterite over the basic dyke has the same mode of occurrence as, and appears to be continuous with, the quite normal-looking laterite exposed in pits nearby and considered to overlie granitic rocks. No evidence was found to suggest that the two varieties of laterite were not formed contemporaneously and under the same conditions. The jointing of the parent quartz-dolerite and evidences of its spheroidal weathering are clearly preserved in the laterite in some parts. The laterite is mottled in colours of red, yellow and brown, the mottling and porosity giving the rock a banded appearance, the banding following the spheroidal weathering pattern,

A thin vertical crack through the laterite was observed to be filled with structureless lateritic material and, embedded in it, small nodules up to about half an inch across and similar to those in the top rubbly or gravelly horizon. The base of the laterite layer is six to seven feet below the original land surface ; it is fairly clearly defined and rests upon a coarsely mottled clay. The bottom of the laterite is not at all even for it projects down into the clay for two or three feet in one place where there is the development of laterite some six to nine inches thick on either side of a joint plane : this joint plane does not appear to continue on down into the mottled clay.

The mottled clay underlying the laterite is a structureless, very pale bluish grey or greenish blue-grey, non-plastic kaolin in which there are harder ferruginous lumps. These are mostly two to four inches across, brick red to bright dragon's blood red in colour, harder than the thumbnail but easily scratched with a knife : the lumps show no definite structure.

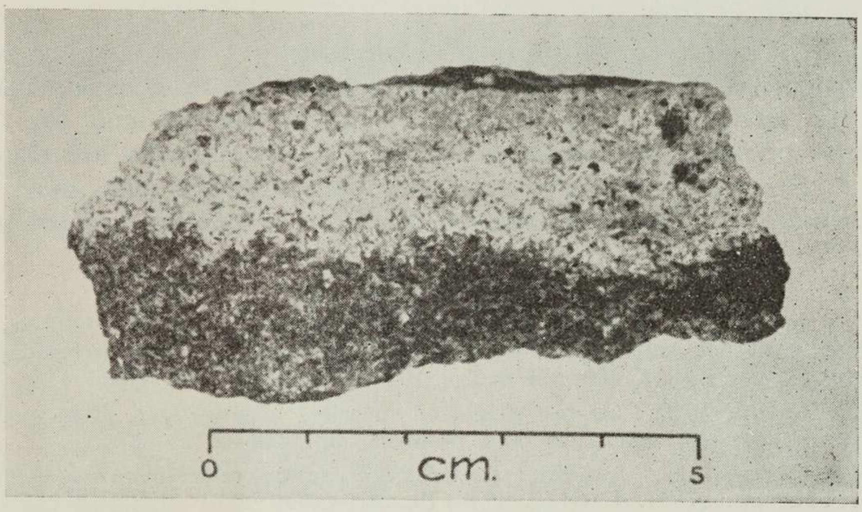
Remnants of the parent quartz-dolerite are to be observed in the profile. One large boulder, four to five feet across, can be seen at the right of the face shown in Plate I, fig. 1. Above this, there is also a much smaller one at about the middle of the laterite layer. The specimen shown in text-fig. 1 was taken from a point about eighteen inches to the left of the small boulder which is the core of the spheroidally weathered block from which the specimen was taken. At the spot where the specimen was taken the colour banding and solution channels are vertical.



Text fig. 1.—"Vermicular" laterite derived from quartz-dolerite, oriented as it was in the laterite horizon.

The large boulder is partly in the laterite stratum but is mostly in the underlying clay horizon. A narrow zone of laterite has developed all around it and is clearly continuous with the fresh quartz-dolerite. This crust is considered to be illustrative of the first-formed primary laterite and a sample was taken for analysis and microscopic examination. Taken from another boulder, the specimen shown in text-fig. 2 illustrates the intimate nature of the junction of quite fresh quartz dolerite and fully developed laterite.

Microscopic examination of the thin sections shows the laterite to be very porous indeed. It consists of pale yellow, lath-shaped relicts of plagioclase felspar in a reddish brown, apparently amorphous mixture of cliachite, hematogelite and limonite ; this latter mixture being quite isotropic between crossed nicols and is considered to have been derived from the ferro-magnesian minerals of the parent rock. The plagioclase relicts consist of microcrystalline material which is considered to be mainly gibbsite with possibly some kaolinite. The faintly yellow non-pleochroic crystals of gibbsite are mostly between five and ten microns across and exhibit a moderate to rather strong anisotropism between crossed nicols. The identification of this material as gibbsite rests upon rather difficult optical work, supplemented by a dyestuff test using the solution of alizarin S (sodium alizarin sulphonate) recommended by Hardy (1931). In some respects this laterite is very similar to the laterite derived from diorite described by Max Bauer (1898).



Text fig. 2.—Small specimen showing the intimate nature of the contact of quartz-dolerite and laterite.

The analysis of the laterite is given in Table 1 and shows that about seventy per cent. of the alumina present is in the form of one or another of the hydrated oxides. Plate II, figs. 2 and 3, are photomicrographs of thin sections of the laterite crust and show the microcrystalline relicts of the plagioclase felspar laths of the parent quartz-dolerite. It will be noted that the structure of the parent quartz-dolerite is very well preserved indeed and that there has been remarkably little disturbance of the alumina/ferric oxide ratio in the course of the weathering of the quartz-dolerite to laterite.

A thin-section was also prepared from the specimen taken from the middle of the laterite stratum and referred to above. This section shows that even here, much of the laterite still retains the structure of the parent rock which is discernible in parts of the massive laterite horizon, even with the unaided eye. As would be expected, there is also much evidence of the filling of general porosity and of solution channels, as shown in the top right-hand quadrant of Plate II, fig. 4, which shows a portion of the slide referred to.

Taking the analyses of the parent rock and the laterite in conjunction with the preservation in the laterite of the structure of the quartz-dolerite and the development of the laterite virtually without disturbance of the alumina/ferric oxide ratio, it is considered that this evidence indicates a process of elimination, in solution in percolating meteoric waters, of those

constituents of the parent rock not still found in the laterite. The possibility of a sort of selective metasomatic replacement of the quartz-dolerite by a mixture of oxides exactly similar in proportions of aluminium and iron to the parent rock is too remote to merit further consideration here, particularly in view of the relatively mobile character, in soils, of iron as compared with aluminium.

This conclusion has far-reaching implications, for no evidence has been found to indicate that the adjacent laterite overlying granitic rocks was not formed in the same manner and under the same conditions as was the laterite examined. It strongly suggests that the laterite of the Darling Range was formed in the manner indicated and not in the way outlined by Stephens (1946).

Hanlon (1945) has described laterite occurrences in New South Wales which are similar to this Parkerville occurrence in that the laterite retains the structure of the parent basalt and at the same time shows little, if any, disturbance of the relative proportions of alumina and ferric oxide. Martin and Doyne (1927), likewise, have described a similar occurrence in which the laterite is derived from norite.

Grateful acknowledgment is made of the assistance given by my colleague, Mr. D. Burns, of the Government Chemical Laboratories, who carried out part of the analytical work on both the quartz-dolerite and the laterite ; the balance of the work was done by the author. Thanks are also due to Mr. H. P. Rowledge, then Deputy Government Mineralogist, now Director of the Laboratories, for his permitting Mr. Burns to assist the author in this way.

REFERENCES.

Bauer, Max, 1898. Beitrage zur Geologie der Seychellen. D. Verwitterung. Laterit-bildung. *Neues Jhrb. f. Min.*, Heft 3, s. 192–219 : *see* pp. 198 et seq.

Campbell, J. Morrow, 1910. On the Origin of Laterite. *Trans. Inst. Min. & Met.*, Vol. XIX., pp. 432–443, discussion and remarks, pp. 444–457.

————————, 1917. Laterite : its Origin, Structure, and Minerals. *Mining Mag.*, Vol. XVII., pp. 67–77, 120–128, 171–179, 220–229.

Hanlon, F. N., 1945. The Bauxites of New South Wales. Their Distribution, Composition and Probable Origin. *Journ. & Proc. Roy. Soc., N.S.W.*, Vol. LXXVIII., pp. 94–112.

Hardy, F., 1931. Studies in Tropical Soils, I. Identification and Approximate Estimation of Sesquioxide Components by Absorption of Alizarin. *Journ. Ag. Sci.*, Vol. XXI., pp. 150–166.

Martin, F. J., and Doyne, H. C., 1927. Laterite and lateritic soils in Sierra Leone. *Journ. Ag. Sci.*, Vol. XVII., pp. 530–547.

Prescott, J. A., 1931. The Soils of Australia in relation to Vegetation and Climate. *Coun. Sci. Ind. Res.* (*Aust.*), Bull. 52.

Simpson, E. S., 1912. Notes on Laterite in Western Australia. *Geol. Mag.*, Dec. V, Vol. IX., pp. 399–406.

Stephens, C. G., 1946. Pedogenesis following the Dissection of Lateritic Regions in Southern Australia. *Coun. Sci. Ind. Res.* (*Aust.*), Bull. 206.

Woolnough, W. G., 1918. The Physiographic Significance of Laterite in Western Australia. *Geol. Mag.*, Dec. VI., Vol. V., pp. 385–393.

PLATE I.

Fig. 1.—Parkerville Tennis Courts, Easterly face showing laterite overlying mottled clay. Large quartz-dolerite boulder at extreme right. Loose surface material has been removed from the left half of the exposure shown.

Fig. 2.—Closeup of profile exposed at right end of Fig. 1. The hammer head indicates approximately the base of the laterite at that spot.

Fig. 3.—Closeup of northerly face showing laterite over mottled clay. It is in this face, near the right side of this view that the laterite extends down along a joint-plane into the clay horizon.

Plate I.

Fig. 1.

Fig. 2.

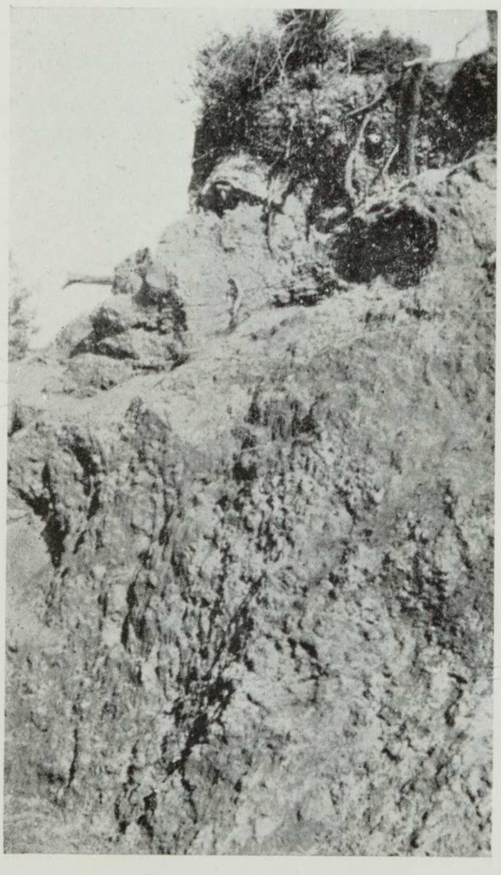


Fig. 3.

PLATE II.

Photomicrographs.

Fig. 1.—Quartz-dolerite from which the laterite developed. (Ordinary light, 20x).

Fig. 2.—Primary laterite showing relict structure. (Ordinary light, 20x).

Fig. 3.—Same field between crossed nicols.

Fig. 4.—Laterite specimen taken from middle of stratum showing light coloured, general y isotropic, spherical bodies which appear to characterise the more aluminous material filling the solution channels and porous areas, but absent from the more ferruginous secondary material.

Fig. 5.—Same specimen as in Fig. 4 showing a solution channel filled with aluminous material and a second, formed later, filled with a more ferruginous mixture.

Plate II.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.